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EXPERIMENTAL EXTINCTION AND ITS
RELATIONSHIP TO PAVLOVIAN CONDITIONED
INHIBITION

by

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The undersigned certify that they have read, and recommend to
the Faculty of Graduate Studies and Research, for acceptance, a thesis
entitled "Experimental Extinction and its Relationship to Pavlovian
Conditioned Inhibition" submitted by Lorne S. Cousins in partial
fulfillment of the requirements for the degree of Master of Science.

ABSTRACT

The current research was designed to determine whether experimental extinction of a classically conditioned response leads to the development of conditioned inhibition. Rats were trained to turn a wheel to avoid unsignaled shock. Then they were given Pavlovian conditioning in which a tone (CS^+) signalled shock. During the first "test" session, presentation of the tone increased the mean rate of avoidance responding.

In the second phase of the experiment Ss received either 0, 20, 320, or 640 Pavlovian extinction trials followed by a summation test for inhibition. During this second "test" session presentation of the tone again resulted in an increase in the avoidance rate in the groups receiving either 0 or 20 extinction trials. However, responding was reduced in both the 320 and 640 groups but only to the original baseline level.

In the third phase of the experiment Ss were given 5 Pavlovian reconditioning trials in preparation for the retardation-of-reacquisition test for inhibition. During this third and final test session presentation of the tone increased responding in all groups but retardation of reacquisition occurred only in the groups receiving either 320 or 640 extinction trials.

The overall results demonstrated that conditioned inhibition did not develop to any of the extinguished stimuli. The retardation obtained in the 320 and 640 groups is interpreted as being due to deficits in attention. Further discussion is focused upon the notion

that excessive experimental extinction, as an operation, produces the following sequence of events: (a) a reduction in response strength to zero, (b) a reduction analyzer strength associated with the detection of the CS and (c) CS habituation. It was finally concluded that the original "extinction beyond zero" phenomenon is nothing more than a post conditioning "CS habituation" effect.

ACKNOWLEDGEMENTS

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DEDICATION

Dedicated to my Mother and Father

for their Patience and Understanding.

INTRODUCTION

Extinctive inhibition is a process originally posited by Pavlov (1927) that leads to decremental learning and is presumeably generated during ongoing experimental extinction in which the conditioned excitatory stimulus (CS^+) is repeatedly nonreinforced. In dealing with experimental extinction as a phenomenon, Pavlov proposed extinctive inhibition as an explanatory concept in an attempt to account for the results of Perelzweig (1905). In this experiment a compound thermal and tactile CS was conditioned to elicit a defence reflex to acid. Then the thermal component, which in isolation was ineffective as a CS, was nonreinforced on three successive trials. The results indicated that this treatment of the weaker thermal component led to a complete secondary extinction of the stronger tactile component and to an almost complete extinction of the reflex to the compound stimulus. In the light of these results Pavlov extended his conception of the degree of extinction to include that which can proceed beyond the point of reducing a conditioned reflex to zero. Accordingly, Pavlov (1927, p.57) states:

"We cannot, therefore, judge the degree of extinction only by the magnitude of the reflex or its absence; there can still be a silent extinction beyond the zero."

Pavlov, then, envisioned extinction as the gradual build up of inhibition that algebraically subtracts from an established level of excitation. In fact, he explained the rhythmic fluctuations in the reflexes observed sometimes during experimental extinction, as a manifestation of the ongoing underlying struggle between the processes

of excitation and inhibition before one of them obtains mastery. Pre-
sumeably when the processes were of equal strength the reflex would be
reduced to zero and when inhibition gained mastery the conditioned
reflex would be reduced to a level below zero.

Extinctive inhibition for Pavlov was but one form of internal inhib-
ition, another being conditioned inhibition. It should be noted here
that the term conditioned inhibition has recently acquired a more
general usage, (Rescorla, 1969c), in the sense of "learned" inhibition,
whereas Pavlov applied the term to the inhibition that develops as a
result of a particular training paradigm. Present day usage of the
phrase conditioned inhibition perhaps better corresponds to Pavlov's
term "internal inhibition" of which there are several types, distin-
guishable only on an operational basis.

Conditioned Inhibition - Definition and Measurement

Perhaps the most adequate definition of conditioned inhibition has
been provided by Rescorla (1969c). He merely construes it as a process
by which a stimulus through learning comes to control a tendency which
is antagonistic to that of a conditioned excitor. This can be inter-
preted to mean that via the process of inhibition a stimulus can acquire
the power of reducing a behavioral change previously attributable to
conditioned excitation. This definition gives conditioned inhibition
a status similar to that of conditioned excitation as will be observed
later.

Before a brief account is given of the procedures that supposedly
lead to the development of inhibition, including experimental extinc-
tion, it may be helpful to elaborate the techniques used in the
measurement of the phenomenon. The most direct method of measuring
inhibition was originally suggested by Pavlov (1927) and has since
appeared in several modified forms (Rescorla, 1965; Weisman and Litner,
1969a). This method, known as the summation test, involves the direct
comparison of the conditioned responding elicited by an excitatory CS
alone, with the excitation elicited by a combination of the above
excitatory CS and a second CS that is suspected to possess inhibitory
power. If the combination produces a reduction in responding when
compared to the effects of the excitatory CS alone, then the second
CS is declared an inhibitor. The notion here is that the processes of
excitation and inhibition are algebraically additive. Several varied
procedures have been employed that demonstrate the use of the summation
logic, e.g. (Pavlov, 1927; Konorski, 1948; Bull and Overmier, 1968;
Kimmel, 1966; Wagner, Thomas & Norton, 1967) but the present thesis
will be concerned with one modified version first demonstrated by
Rescorla and LoLordo (1965) and subsequently adopted by Weisman and
Litner (1969a). This technique involves a reduction in the general
level of conditioned excitation present in an unsignalled (Sidman, 1953)
avoidance situation. In this experimental setting avoidance behavior
is under the control of temporal events such that a given response
postpones the occurrence of the aversive stimulus for a fixed period

of time. Absence of responding results in a series of shocks that are
separated by rather brief time intervals and continue to occur until
postponed by the next response. Thus, behavior in the Sidman avoidance
situation can be construed as being maintained by a general level of
conditioned fear which is not under the control of an explicit CS.
However, there are more than likely a variety of cues eliciting
excitation in Sidman avoidance and it is still quite conceivable
to suppose that changes in behavior produced by explicit stimuli super-
imposed on the avoidance baseline of responding are the result of a
summation process with the established level of excitation in the
avoidance situation. Correspondingly, reductions in response rate have
been interpreted as evidence for conditioned inhibition of fear, and
increments in responding, of course, as evidence for conditioned
excitation (Rescorla & LoLordo, 1965; Weisman & Litner, 1969a, 1969b;
Kamano, 1968).

A second class of procedures developed to demonstrate the presence
of conditioned inhibition centres around the acquisition of responses
during excitatory conditioning. This measurement technique was
initially suggested by Pavlov (1927) in his discussion of the restor-
ation of an extinguished conditioned reflex. He noted that it was
possible to accelerate the restoration of a conditioned reflex by
either presenting the unconditioned stimulus in isolation, or reinstating
the original CS-UCS contingency. In relating this rapidity of restor-
ation phenomenon to the depth of extinction concept Pavlov (1927, p.59)
states:

"If the extinction has not been carried very far, a single appli-
cation of the unconditioned stimulus is often sufficient to restore
the reflex to full strength; but if the extinction has been made
profound repeated reinforcements are necessary. This means of accel-
erating the recovery of the extinguished reflex affords another method
of measuring the depth of extinction."

The logic here focuses again on the notion that the processes of
conditioned excitation and inhibition are subtractive of one another.
If the former is true, then it would seem reasonable to suppose that a
previously inhibitory stimulus would be more difficult to convert to
an excitatory one than a stimulus of neutral value, and that a paradigm
that simultaneously produced inhibition and excitation to a CS would
markedly retard the acquisition of the excitatory conditioned response.
This notion has received wide acceptance and several experiments have
reported retarded acquisition of an excitatory CR as evidence for
conditioned inhibition (e.g. Konorski, 1948; Hammond, 1968; Rescorla,
1968a).

Procedures for Generating Conditioned Inhibition

Before mention is made of the efficacy of simply non-reinforcing
a stimulus as a procedure leading to the development of inhibition, brief
consideration will be made of other contrasting procedures suggested
initially by Pavlov (1927). According to recent contingency formu-
lations of classical conditioning (Rescorla, 1967, 1969a) all inhibition

paradigms, except experimental extinction and latent inhibition,
specify a very particular relationship between the CS and UCS. In all
cases the CS or portions of it and the UCS are negatively correlated in
time such that the CS and UCS occur on independent trials but the CS
never predicts the occurrence of the UCS. In fact the first procedure
to be considered here provides such an arrangement of the CS and
UCS. There is ample evidence that negatively correlating the CS and
UCS reliably produces conditioned inhibition (Rescorla & LoLordo, 1965;
Weisman & Litner, 1969a, 1969b, 1971).

This negative correlation of conditioning events is also evident
within the discriminative Pavlovian conditioning paradigm. In this
procedure CS^+ is consistently followed by the UCS and CS^- is not.
Pavlov claimed that in this situation CS^- came to control a tendency
opposite to that of CS^+. That inhibition accrues from such an arrange-
ment of conditioning events is a well documented fact (Pavlov, 1929;
Weisman & Litner, 1969b).

A third procedure for producing conditioned inhibition is that of
inhibition of delay. This paradigm utilizes an extended CS-UCS
interval and it is often noted that the CR becomes confined to the
later part of the CS. Pavlov (1927) believed this occurred because
the early part of the interval became inhibitory. Subsequently
Rescorla (1967a) found that the onset of an extended CS suppressed
ongoing avoidance behavior. Conversely as the CS continued, the
avoidance rate increased monotonically to a level well above the pre-CS

rate, thereby confirming Pavlov's suspicions. These results have also been replicated using a trace conditioning procedure (Rescorla, 1967a).

Finally, it is not difficult to conceptualize how the backwards conditioning paradigm utilizes the negatively correlated relationship between the CS and UCS. However, it was originally supposed that the CS in this situation acquired inhibitory properties because it signaled termination of the UCS (Konorski, 1948). But as Rescorla (1969c) points out it definitely appears that a stimulus associated with UCS termination becomes inhibitory only if it signals a period free from the UCS, this period normally being the inter-trial interval. Indeed Moscovitch and LoLordo (1968) have provided evidence on this matter, in finding that stimuli signaling a long minimum shock-free period always become inhibitory, and that stimuli correlated with UCS termination only become inhibitory when they signal periods free from the UCS. Recently Siegel and Domjan (1971) have further demonstrated that the backwards conditioning paradigm can be a viable procedure for generating conditioned inhibition.

Experimental Extinction and Inhibition

As stated earlier experimental extinction is a procedure that supposedly leads to the development of conditioned inhibition, yet does not provide the negative correlation between the CS and UCS. This fact has led some investigators to suppose that extinction is not a sufficient nor necessary condition for the development of inhibition,

yet surprisingly enough there is very little evidence on this matter.

For example, Pavlov has never presented evidence indicating that an

extinguished CS reduced the CR elicited by a known excitor or that an

extinguished CS is more difficult to recondition than a novel CS.

Some isolated European studies have reported extinguished CS's as

conditioned inhibitors but Rescorla (1969c) points out that these

studies lacked the use of proper control groups. Also, in these

experiments, extinction of a CS was carried out in the context of

simultaneous continuous reinforcement of other CS^+'s, resulting in the

conversion of the extinguished CS^+ to a discriminative CS^-. In any

case, the above evidence can only lead one to reserve judgment on

whether simple nonreinforcement of a previously reinforced CS is a

sufficient and or necessary condition for endowing a stimulus with

inhibitory properties.

The American literature contains evidence related to the problem

that is about as uninformative as the European literature. This is

certainly true for studies utilizing the summation test procedure. For

example, LoLordo and Rescorla (1966), using a fear conditioning

situation, attempted to demonstrate that the conditioned response

elicited by an excitatory CS would be more highly resistant to experi-

mental extinction if it were always followed by a known conditioned

inhibitor of fear during extinction. They found for both the simple

extinction and the "protected" groups that after approximately 40 trials

the fear response during the CS had extinguished to zero. However, this

study provides little insight into the question of whether the observed

reduction in responding was due to the process of inhibition or some other process, since perhaps a greater number of extinction trials is necessary in order to reduce the conditioned fear response beyond its zero level and thus convert the excitatory CS^+ into an inhibitory CS^-.

In another study, investigating the efficacy of the inhibition of delay paradigm in fear conditioning, Rescorla (1967a) found that 300 extinction trials reduced the excitatory and inhibitory effects of the early and later portions of the extended CS, respectively, to zero. However, both conditioning and extinction trials were conducted during ongoing unsignaled avoidance responding, thus allowing for the inter- action of the conditioned fear generated from the Pavlovian training and that generated from the avoidance schedule itself. Perhaps some of the inhibition that could have been developing from the experimental extinction was retarded by the excitation in the avoidance situation per se, and any evidence of conditioned inhibition detectable by the summation procedure would require further extinction training. Weisman and Litner (1969b) using a similar procedure to that of Rescorla, found that the conditioned fear response was reduced to zero after approximately 100 trials of "on baseline" extinction training. Again, one cannot reasonably exclude the possibility of the extinction below zero phenomenon occurring in such a procedure, since sufficient evidence for extinctive inhibition may require a considerably greater number of extinction trials especially during ongoing avoidance responding.

Evidence bearing on the question of extinctive inhibition has also accumulated from studies using the retardation-of-acquisition procedure, and it presents a slightly clearer picture. There appears to be little doubt that an extinguished conditioned stimulus will recondition faster than a truly novel stimulus. Perhaps the most convincing evidence on this matter has been presented by Konorski and Szwejkowska (1950). These authors, using salivary conditioning, carefully observed $\underline{S}$s undergoing chronic extinction and found that once extinction was complete, restoration of the conditioned reflex by reinstitution of the CS-UCS contingency was both rapid and abrupt. They concluded that whereas resistance to extinction of the CS is quite strong, resistance to restoration is quite minimal, and further suggested that the inhibition generated during experimental extinction was rather unstable and weak. These results were replicated using a defense reflex (Konorski and Szwejkowska, 1952a) and have also been obtained by other investigators (Pavlov, 1927; Kamano, 1968).

It should be noted at the present time that extreme caution must be exercised in the interpretation of the retardation of relearning results (Rescorla, 1969c), as it may still be necessary to invoke a process like inhibition in the explanation of experimental extinction. Indeed, organisms that have received a number of conditioning trials probably attend to the particular stimulus dimension of the CS. In the terms suggested by Sutherland and Mackintosh (1971) the analyzer associated with detection of the CS is switched in and strengthened. An analyzer for these authors is simply a mechanism for classifying stimulus input,

and each analyzer analyzes stimulus input along a particular dimension. Furthermore, analyzers are strengthened when their outputs make accurate predictions concerning events (e.g. the UCS) of importance to the animal. An additional assumption in their model is that strengthening of the relevant analyzer results in a weakening of the total strength of other analyzers (e.g. those related to situational cues) by a comparable amount. However, when the relevant analyzer no longer makes accurate predictions about the UCS all analyzers revert to their base level.

It is worth noting here that Sutherland and Mackintosh are advocating a two process theory of learning. Accordingly, these authors state (Sutherland and Mackintosh, 1971, p.33):

"... animals must learn both to attend to the relevant stimulus dimension and to attach the correct responses to stimuli having different values on that dimension...."
This seems to suggest that response strength is somewhat independent of analyzer strength.

In any event, it would not be unreasonable to expect accelerated reconditioning following extinction since facilitation of relearning could occur on a purely selective attentional level. For example, there may either be some residual undetectable excitation associated with an extinguished CS (Rescorla, 1969c) or, even though response strength is effectively reduced to zero, the analyzer strength (Sutherland and Mackintosh, 1971) associated with the CS may not have yet returned

to its base level. In either case, once conditioning trials are restored, accelerated reacquisition is expected. This facilitated recovery of conditioned responding vis à vis attentional processes could perhaps overshadow any effects due to the proposed inhibition (Pavlov, 1927) generated by the extinction procedure. Also, it is plausible that a single presentation of the UCS may yield a CR after extinction is complete, yet inhibition may not have been built up to that part of the stimulus complex. The point to be taken here is that although an extinguished CS may well acquire the properties of a conditioned inhibitor a retardation test may fail to detect it.

CS Habituation or "Latent Inhibition"

A second procedure that supposedly produces conditioned inhibition in the absence of a negative correlation between the CS and the UCS is that of CS habituation or the "latent inhibition effect". This procedure simply involves repeatedly nonreinforcing a neutral stimulus in isolation, and then testing its ability to serve as a CS. Konorski and Szwejkowska (1952b) found that repeated nonreinforced pre-exposure to a neutral stimulus resulted in protracted and deficient acquisition of conditioned responding when conditioning trials were begun with the pre-exposed stimulus serving as the CS. These authors gave the following inter-pretation to the above evidence (Konorski, 1967, p.318):

"Therefore we may conclude that the stimulus by being merely presented without reinforcement acquires strong and permanent

inhibitory properties manifested by its subsequent resistance to conditioning."

This phenomenon, now known as "the latent inhibition effect" (Lubow and Moore, 1959) has received widespread experimental support (e.g. Anderson et. al., 1969; Carleton and Vogel, 1967; Lubow, 1965; Pavlov, 1927; Reiss and Wagner, 1971; Siegel and Domjan, 1971) with very few exceptions (e.g. Suboski et. al., 1964).

An important point to note here is that all of the evidence cited thus far concerning latent inhibition was derived using the retardation-of-acquisition test for inhibition. Again, a problem concerning the measurement of inhibition is encountered since an alternative explanation with respect to the latent inhibition findings is extremely feasible (Rescorla, 1969c). It may be that repeated nonreinforced pre-exposure to a CS develops deficits in attention to that particular stimulus dimension. This general decrement in attention can be construed as reductions in arousal eliciting properties of the stimulus, attenuation of the orienting reflex or whatever, depending on one's theoretical biases. Aside from these postulated mechanisms of habituation we do know that simple repeated nonreinforced presentations of a stimulus leads to decrements in measureable responding. In fact it is in these terms that habituation is defined (Grove & Thompson, 1969). It is not unreasonable to suppose that the kinds of changes produced by habit-uation have an important bearing on the attention commanding properties of a stimulus per se, and that these changes would affect the ability

of that stimulus to serve as a CS, in a negative manner. As Rescorla (1969c) aptly states:

"It is reasonable to expect that an organism which comes to the experimental setting attending to stimulus dimensions other than that of the CS will be retarded in the development of a CR."
Thus we can infer that retardation of the development of a CR does not necessarily indicate the presence of conditioned inhibition.

Conceptually, the notions of conditioned inhibition and attention are clearly distinguishable. It will be recalled that conditioned inhibition alludes to an effect that is specifically opposite to that of conditioned excitation; also a conditioned inhibitor is specific to the reduction of a particular response. This is evidenced in Konorski's (1967) finding that retardation in salivary conditioning occurred to a former CS⁻ for food but rapid defence conditioning occurred for the same CS. In contrast, attention, as the term has typically been conceptualized refers to the efficacy of a stimulus in producing a response independent of what that response may be. It is also possible to operationally distinguish between attention and inhibition as will be seen in the next section.

Measurement of Inhibition Reconsidered

The measurement problems outlined above in relation to experimental extinction and latent inhibition can be circumvented by the use of a sequential combination of the summation and retardation measures in

experiments designed to investigate conditioned inhibition (Rescorla, 1969c). This notion is especially critical when one considers that the summation test results, alone, are also not free from alternative interpretations, such as generalization decrement. However, evidence from the sequential use of both procedures should resolve the problem. Clearly, beyond all reasonable doubt, a conditioned stimulus that both produces a reduction in a level of baseline excitation and is slower to convert to an excitatory stimulus than a novel stimulus, must have acquired inhibitory or inhibitory-like power. Or more parsimoniously, a stimulus that affects strictly the attention of an organism should not behave like conditioned inhibitor on both the summation and retard-ation-of-reacquisition test procedures. The above deduction makes it possible to distinguish between inhibition and attention and to control for their confounded effects.

Reiss and Wagner (1971) have recently conducted the relevant study in an attempt to conclusively determine whether a pre-exposed stimulus functions directly as a conditioned inhibitor. In their first experi-ment these authors simply replicated the well-documented finding that pre-exposure leads to retarded development of conditioned responding. However, the results of their second experiment proved particularly enlightening. In this study Reiss and Wagner gave either 1380 (A) or 12 (B) CS pre-exposures to two groups of Ss. They discovered via a summation test with a conditioned excitor (C), that over nonreinforced test presentations of the compounds AC and BC, the more frequently

exposed CS A did not evidence greater conditioned inhibitory effects than the less frequently exposed CS B. This effect is opposite to that expected if A, supposedly acquired more conditioned inhibitory properties than B. Hence these authors suggest that the latent inhibition effect does not involve the acquisition of a CR inhibitory tendency and that latent inhibition be properly termed CS habituation.

In a similar fashion the present study was designed in a further attempt to investigate the phenomenon of experimental extinction and its relationship to Pavlovian conditioned inhibition. The research to be presented here employed both of the standard measures of conditioned inhibition in order to determine whether experimental extinction transforms a CS^+ via the process of inhibition into a reliable CS^-. It is believed that a sufficiently wide range of extinction trials were used such that ample opportunity would be provided for the occurrence of the "extinction beyond zero" phenomenon proposed by Pavlov (1927).

The results of the present work have, of course, a bearing on extinctive and inhibitory phenomena per se, but they also provide evidence that has important implications for a provocative new theory of the operation of reinforcement in Pavlovian conditioning, set forth recently by Wagner and Rescorla (1972). This model has had great success in accounting for a variety of data from Pavlovian conditioning and has special implications for inhibition and decremental learning. The model will not be presented in detail here, except for the basic propositions, such that it may be distinguished from traditional learning theories.[1] Basically, the theory is unique in terms of its

assumptions concerning what happens when several CSs are reinforced by the same UCS on a particular trial. Wagner and Rescorla (1972) have selected the option that the associative value of each of the stimuli in the compound is modified only until the collective value of the compound reaches some arbitrary asymptotic level. Previous theories (e.g. Hull, 1943; Spence, 1956) have assumed that the associative value of the components will be modified until each individually reaches some asymptotic level.

In order to account for the mode in which reinforcement and non-reinforcement combine to influence learning on subsequent trials of either variety, these authors followed the assumption that the asymptotic level of associative strength decreases with decreasing UCS intensity and that nonreinforcement differs from reinforcement only in having a value of associative strength that would most reasonably be expected to be associated with zero UCS intensity, i.e. zero. Thus nonreinforcing a CS possessing a particular associative strength should not have a constant effect but will depend upon the associative strength of other cues with which it is in compound (these cues would, for example, be background cues in the experimental situation). According to this model there is no special inhibitory process, as inhibition is simply described in terms of negative associative strength. But for a neutral cue to be made inhibitory, as a result of nonreinforcement, it must be nonreinforced in compound with other cues which make the aggregate associative strength of all cues positive. It should be noted that this

set of operations is very different from those employed in the experi-
mental extinction situation. An example may be helpful. Imagine a
paradigm where one stimulus A is repeatedly reinforced obtaining an
associative strength V_A, while a compound, AX, is nonreinforced
obtaining an associative strength of $-(V_A + V_X)$. A stimulus, X, so
treated, becomes a conditioned inhibitor whereas simple nonreinforcement
of AX alone is inadequate to produce that result. In terms of the
model, the conditioned inhibition procedure results in a large positive
value for V_A and hence a large negative value for $-(V_A + V_X)$ on the
compound trials. Consequently, an X which has an initial V value of
zero will receive only decrements and take on negative V values,
i.e. become a conditioned inhibitor. In the absence of a positive
value for V_A, as in simple repeated nonreinforced presentation of AX,
this consequence would not be expected.

The implication of the preceding discussion is simply that Wagner
and Rescorla have specifically arranged that their model does not
predict that simply nonreinforcing a previously reinforced CS, in
isolation, will result in an inhibitory cue. Although the Wagner and
Rescorla (1972) model is essentially a more formalized presentation of
the contingency notions regarding inhibition, mentioned earlier, it
clearly does generate predictions that are at odds with Pavlov's
original contention that an extinguished stimulus may become a con-
ditioned inhibitor.

Experimental Introduction

The present experiment was designed to test the hypothesis that experimental extinction leads to the development of conditioned inhibition in the following fashion. Firstly, a baseline of avoidance responding was established utilizing a Sidman avoidance schedule. This free operant system of scheduling aversive events typically generates stable response rates and changes in avoidance rate correlated with the introduction of independently conditioned stimuli provide a sensitive measure of the effects of those stimuli.

In the next phase of the experiment it was necessary to independently establish Pavlovian conditioned excitation in order that the effects of presenting CS^+ alone during extinction could be assessed. Subsequent to testing for conditioned excitation across all groups following Pavlovian conditioning, extinction trials were begun, again in the independent Pavlovian apparatus. Ss received either 0, 20, 320, or 640 trials of Pavlovian extinction and a summation test for inhibition followed immediately by superimposing the extinguished stimuli on the avoidance baseline of responding.

Finally all Ss received 5 additional Pavlovian CS-UCS trials in preparation for the retardation test for inhibition. As mentioned earlier it is the combination of this measure and the summation test that is critical in the present study and sets it apart from earlier attempts to answer the experimental question.

Method

Subjects

Thirty naive female hooded rats obtained from Les Medicos Breeding Laboratory were used as Ss. All Ss were retired breeders about 5 mo. old and weighed approximately 300 grams at the commencement of the experiment.

Apparatus

Avoidance sessions were conducted in an operant chamber, 8½ x 11 x 9½ inches, that was fitted with a wheel turn manipulandum. One wall of the chamber supported a 4½ inch-long cylinder, mounted so that the axle was situated outside the chamber. Stainless steel grids, spaced at ½ inch intervals around the circumference of the cylinder formed the wheel. A cam on the axle closed a switch four times during each complete 360° rotation of the wheel. Each switch closure operated a "response feedback" relay mounted next to the chamber. The wall on which the wheel was mounted and the opposite wall were aluminum panels; the remaining walls were ¼ inch intervals across the floor of the chamber. Four identical operant chambers were used.

Pavlovian conditioning was administered in two identical 8 x 4 x 6 in. wooden chambers. The side walls of each chamber were painted with alternating flat black and white vertical stripes and the top was constructed of clear Plexiglass. Stainless steel tubular grids were spaced at 3/4 in. intervals across the floor of each Pavlovian

conditioning chamber.

Lafayette Instrument shock generators were set to deliver brief .5-sec. inescapable scrambled shocks at .75-ma. to the grids of both the avoidance and the Pavlovian training chambers. A 2,800 Hz tone produced by a Sona-lert device could be presented at 85 db., re .0002 dynes/cm.^{2}, to each chamber. Each of the avoidance chambers was housed in a separate sound resistant enclosure, while the Pavlovian chambers were housed together in a single sound attenuating chamber. Programming modules, tape programmers, and print out counters, all used throughout the course of the experiment, were located in a separate control room.

Procedure

Baseline Training. In order to test the effects of the various stimuli in the experiment an unsignalled avoidance baseline of responding was established. All Ss received four days of training on an unsignalled (Sidman, 1953) avoidance schedule in which they were required to turn a wheel in order to avoid shock. If S did not rotate the wheel at least ¼ turn, shock was delivered to the grids every 5 sec. Each wheel turning response postponed the occurrence of the next shock for 20 sec. Thus the shock - shock interval was 5 sec. and the response - shock interval was 20 sec. All daily avoidance sessions were 70 minutes in length with the first 10 minutes being considered "warm up", during which no experimental procedure was scheduled and no responses or shocks were tallied with the responses and shocks recorded within the

succeeding 1-hour session proper.

After Day 4 six Ss were discarded from the experiment because they failed to meet an arbitrary criterion of less than 20 shocks during the four avoidance sessions. The remaining 24 Ss were assigned to one of four experimental groups of 6 rats each. These groups were to subsequently receive either 0, 20, 320 or 640 extinction trials after Pavlovian conditioning. Throughout the following three phases of the experiment Sidman avoidance sessions were alternately interspersed between Pavlovian sessions in order to maintain a stable rate of baseline responding for subsequent testing.

Pavlovian Conditioning. During this phase of the experiment beginning on Day 5 all Ss in the four extinction groups were confined in the small chambers and received 20 Pavlovian conditioning trials. In these sessions CS^+ in the form of a tone was presented for 5 sec. followed immediately by a .5-sec. .75-ma. electric shock. The ITI between CS-UCS presentations averaged 3 minutes. An interspersed Sidman avoidance session followed on Day 6 and on Day 7 a summation test of conditioned excitation was carried out in which CS^+ was superimposed on the avoidance baseline of responding. On this and all subsequent tests the 5-sec. tone was presented 20 times and was programmed with an average ITI of 3 minutes. Unavoidable shocks administered during Pavlovian conditioning sessions were omitted but shocks programmed by the ongoing Sidman schedule were delivered during all test sessions.

Extinction Training. Pavlovian extinction sessions began on Day 8 for all Ss except those in the group receiving 0 extinction trials. Ss in this group were simply given a second summation test on Day 8. It was expected that the inclusion of a 0 extinction group would provide experimental control for the possible "on baseline" extinction that could occur during the 20 nonreinforced presentations of the tone at the various test stages of the experiment.

The 20 extinction group received 20 nonreinforced presentations of the 5-sec. tone in the Pavlovian conditioning apparatus with an average ITI of 3 minutes. This was followed by an unsignalled avoidance retraining session on Day 9 and summation test on Day 10. This group was included in order to marshal the effects of a slight amount of extinction of Pavlovian conditioned fear on free operant avoidance responding.

The selection of the 320 and 640 extinction trials for the present experiment was based largely on the results of pilot work. The initial results of a summation test indicated that complete extinction of Pavlovian fear did not occur at 160 trials but did occur at 320 trials. It was therefore decided to include a group receiving 320 trials in the experiment proper. Upon determining a level at which experimental extinction was complete it seemed reasonable to suppose that 640 extinction trials (32 times the number of original training trials) would provide more than enough extinction training to generate detectable inhibition, if this were at all possible.

Extinction training for both the 320 and 640 groups, was divided into daily sessions consisting of 80 nonreinforced presentations of CS^+. Pavlovian extinction sessions were alternated with Sidman avoidance retraining sessions until the full quota of required extinction trials was reached for each group. Summation testing for inhibition occurred on the day following the last interspersed Sidman session for both of the above groups.

Reacquisition Training. Upon completion of the extinction phase of the experiment all groups, including the 0 group, were given 5 reconditioning trials, in which the original CS-UCS contingencies were reinstated, in preparation for the retardation-of-reacquisition test for inhibition. At this point it seems best to explain the reason for the incorporation of a fifth group in the experiment. It will be recalled that in order to utilize the retardation measure to indicate the presence of inhibition it is necessary to demonstrate that the extinguished or inhibitory CS is more difficult to recondition than a novel CS. In the present experiment then, it was necessary to include a novel CS group that received only 5 Pavlovian conditioning trials such that comparisons between it and the other reconditioned groups could be made. After the four days of baseline training this reacquisition control group received five, 5-sec. tones, followed by shock, with a 3 minute ITI separating CS-UCS presentations.

All groups received a Sidman retraining session that was interspersed between the 5 trials of Pavlovian reconditioning and the final retardation test for inhibition.

Results

All statistical analyses to be presented in this section were conducted after the data had been converted to a relative measure of conditioned responding as per Weisman and Litner (1971). This was achieved by dividing the number of responses during the 5-sec. CS presentations by the number in the 5-sec. period preceding the onset of the CS. Calculated in this fashion a ratio greater than 1 indicates conditioned excitation, a ratio less than 1 indicates conditioned inhibition and a ratio of 1 indicates no conditioned responding.

The rates of responding during 5-sec. intervals prior to, during and following the presentation of CS^+ after Pavlovian conditioning are displayed graphically in Figure 1. Inspection of the curves in Figure 1 indicates that relatively stable rates of baseline responding were attained in all groups during the three pre-CS 5-sec. intervals and that a marked increment in responding occurred attendant upon the presentation of CS^+. However, the increased ratio obtained for CS^+ remained relatively constant across conditions, as indicated by the mean $\frac{CS}{PRE\ CS}$ ratios presented for all groups in the acquisition section of Table 1. An analysis of variance conducted on the acquisition ratios showed no differences between these means (F = .25, df = 3/20, NS, see Appendix A, Table A-1). Further reference to Figure 1 also suggests that post CS^+ responding gradually returned to its original baseline level by the third 5-sec. interval for all groups.

Figure 2 describes the $\frac{CS}{PRE\ CS}$ function of both extinction and
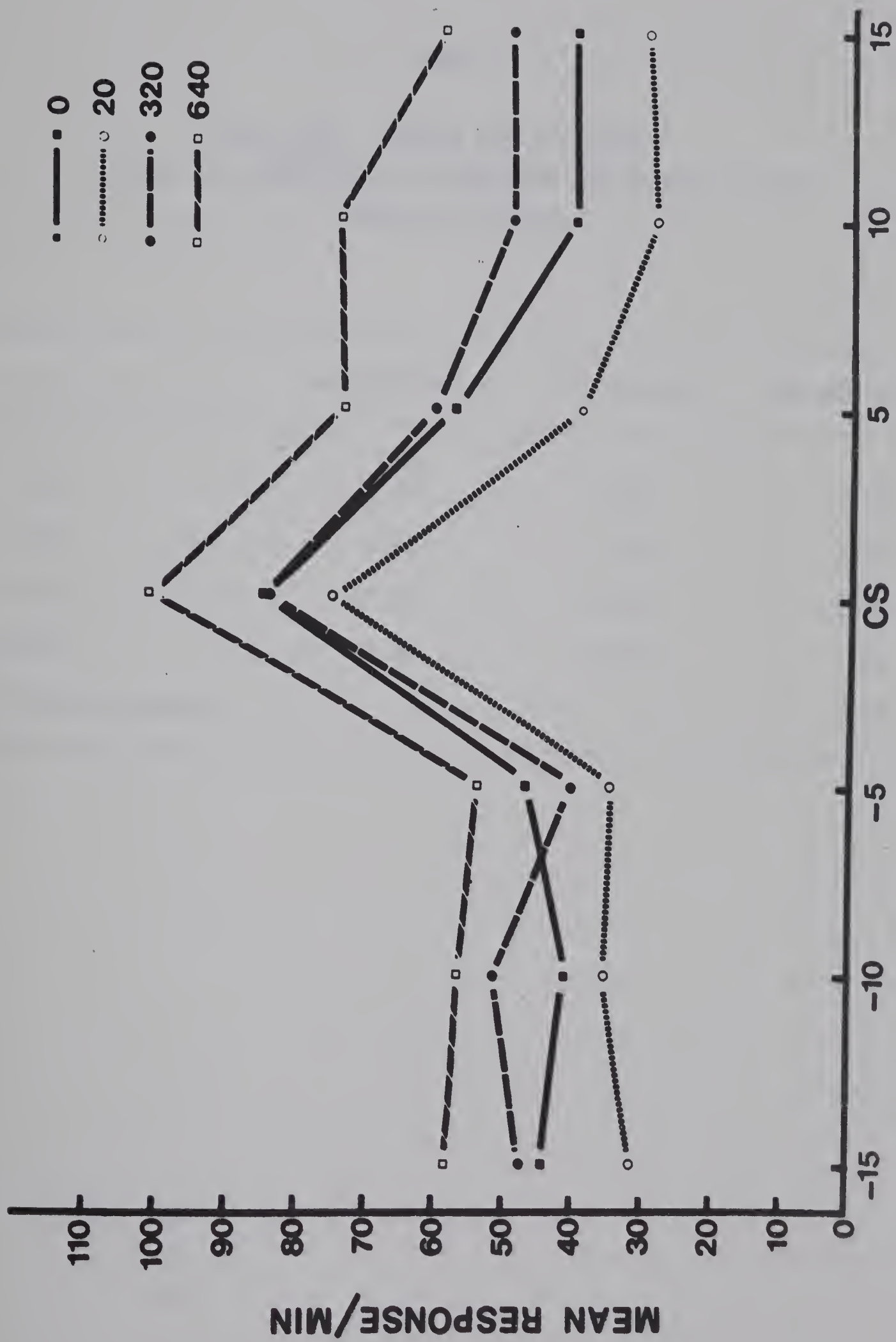
Figure 1. Mean response rates during successive 5-sec. periods prior to, during (CS) and following tone presentations during the test session after Pavlovian conditioning.

TABLE 1

MEAN $\frac{CS}{PRE\ CS}$ RATIOS FOR ALL GROUPS
OVER THE ACQUISITION, EXTINCTION AND REACQUISITION
PHASES OF TESTING.

	Acquisition	Extinction	Reacquisition
0	2.36	2.15	2.18
20	2.28	1.73	1.70
320	2.20	0.83	1.34
640	1.84	0.99	1.35
5 trial control			1.92

reacquisition training over the four levels of extinction trials administered during the experiment. These same means are also presented in Table A-1. An analysis of variance performed on the above data demonstrated a significant effect of extinction trials (F = 4.69, df = 3, 20, p < .05) but neither the phase of testing main effect nor the phase x extinction trials interaction were significant (see Appendix A, Table A-2). It appears that both 320 and 640 trials of extinction produced large decrements in the magnitude of conditioned excitation established during Pavlovian conditioning but neither number of trials resulted in the extinction proceeding beyond the "zero". Conditioned responding only returned to the original baseline level.

Although the phase x trials interaction was not significant, closer inspection of Figure 2 suggests that this interaction is largely obscured by the remarkable similarity in conditioned responding, following extinction and reacquisition training, of the groups receiving 0 and 20 extinction trials, respectively. It is clearly evident that 20 trials of Pavlovian extinction training produced minimal decrements in conditioned excitation, thereby allowing little opportunity for the effects of reacquisition to be exhibited. However, orthogonal comparisons indicated that a significant amount of reacquisition did occur at the 320 level (t = 1.96, df = 20, p < .05) but at 640 trials of extinction, recovery of conditioned responding was not significantly above the extinguished level (t = 1.36, df = 20, NS).

The single data point in Figure 2 represents the ratio of conditioned

EXTINCTION

REAQUISITION

REAQUISITION CONTROL
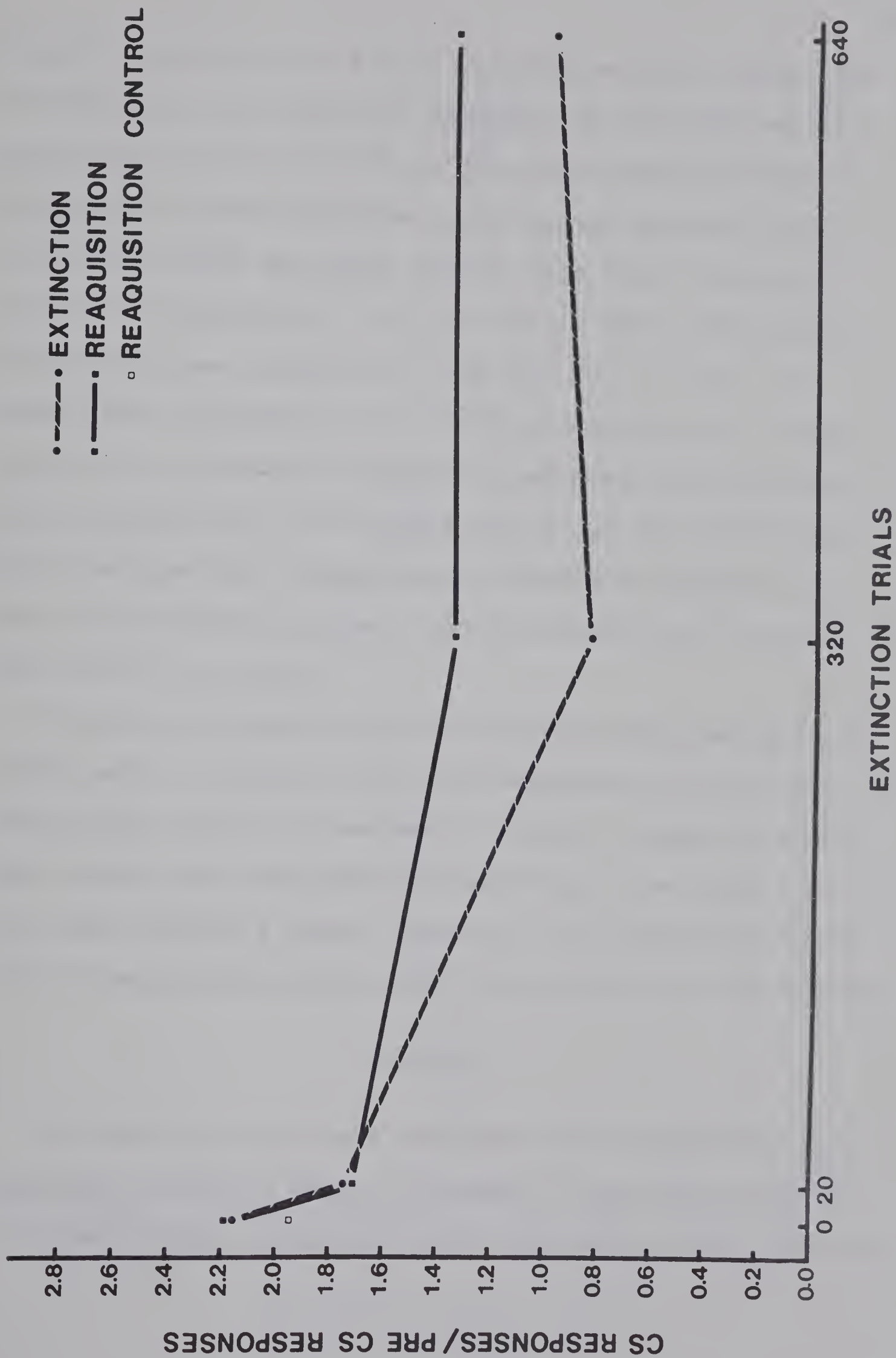
CS RESPONSES/PRE CS RESPONSES

EXTINCTION TRIALS

Figure 2. Mean $\frac{CS}{PRE\ CS}$ ratios of conditioned responding for all experimental groups over the extinction and reacquisition phases of testing.

29.

responding attained by the 5 trial reacquisition control group. The

critical comparisons between the performance of this group and the

reacquisition scores of the 320 and 640 groups demonstrated that

significantly greater conditioned excitation was attained by the 5

trial control group than either the 320 groups after 5 trials of

reacquisition training (t = 1.77, df = 20, p < .05) or the 640 group

following the same treatment (t = 1.74, df = 20, p < .05). It

appears that reinstatement of the CS-UCS contingencies for 5 trials

resulted in a significant increment in conditioned excitation above

the extinguished level for the 320 group, but not for the 640 group,

and in each case this increment was not sufficient to approach the

level of conditioning attained by simply presenting the CS paired

with the UCS for 5 trials.

The rates of responding for the 320 and 640 groups during 5 sec.

periods prior to, during and following presentation of the CS after

reacquisition training are presented in Figure 3. Comparison of the

wheel turning rates during the CS in both Figure 3 and Figure 1 for

each group, provides a clearer indication of the magnitude of retard-

ation of reacquisition obtained after 320 and 640 trials of extinction.

Discussion

The results of the present experiment seem to suggest that while

experimental extinction produces decrements in conditioned responding,

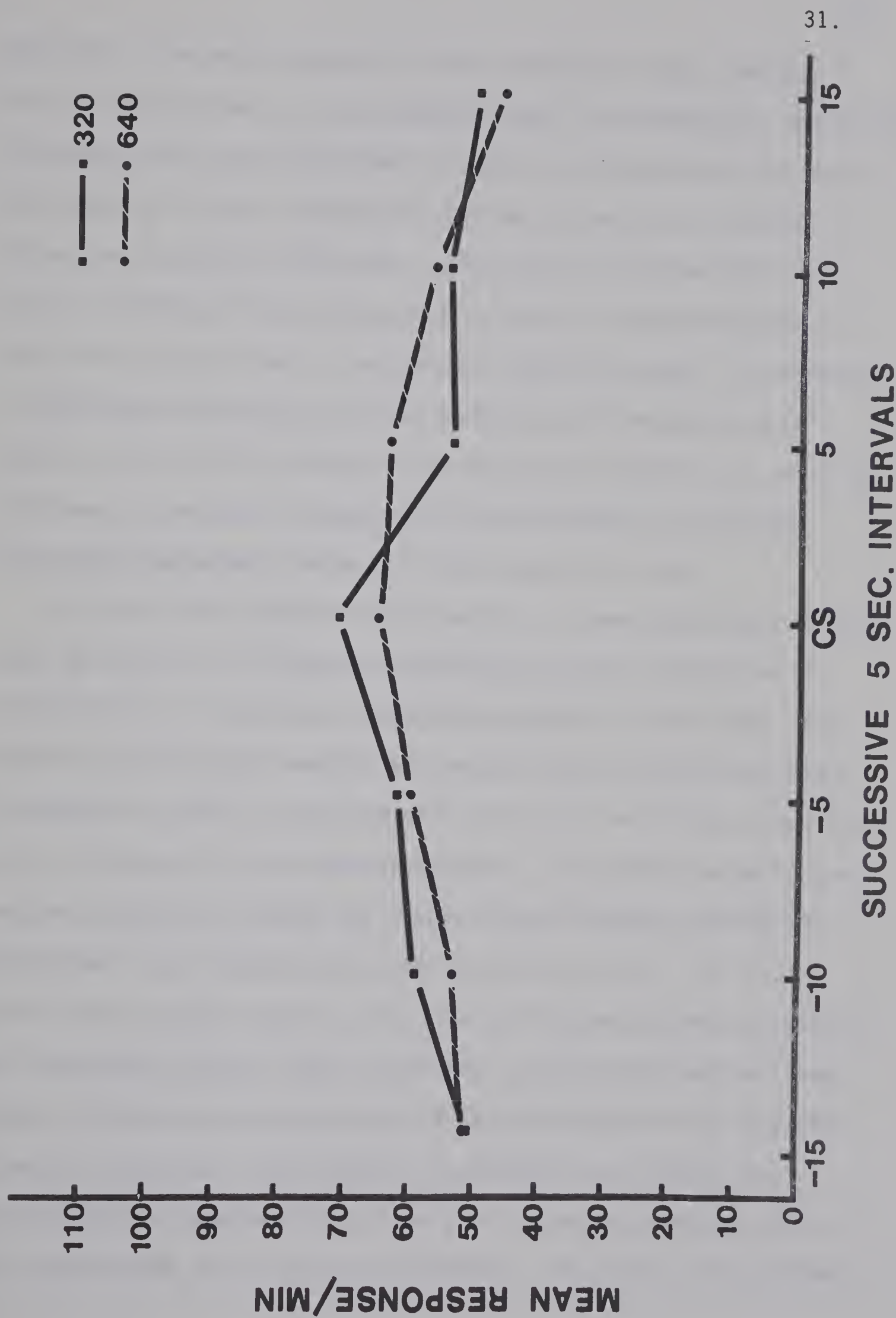the process which is responsible for these decrements is not conditioned

Figure 3. Mean response rates during successive 5-sec. periods prior to, during (CS), and following tone presentations during the test session after reacquisition training.

inhibition. The major impetus for this conclusion stems from the post-extinction results of the summation test for inhibition. While 320 extinction trials were sufficient to reduce conditioned fear to zero, absolutely no further reduction in fear was observed by extending extinction training to 640 trials. This result is antagonistic to Pavlov's (1927) position that extinction leads to the development of inhibition and that there is extinction "beyond the zero". Presumeably, if inhibition were being generated during nonreinforcement and CS^+ became a CS^-, then this effect should have been evident in at least the 640 group, by having the magnitude of the decrements in avoidance responding proceed well below the initial baseline level.

In view of the summation test results, it seems desireable at this stage to provide an alternative explanation for the retardation of reacquisition of conditioned responding obtained in this study. The results have indicated that 320 extinction trials are both sufficient to produce no effect on the summation test and to retard the acquisition of an excitatory CR to the extinguished CS. This effect seems to have reached asymptote at around 320 trials since no further significant developments were obtained using 640 extinction trials. At first glance these results appear to disagree with those obtained by Konorski and Szwejkowska (1950, 1952a) and others. As mentioned earlier these authors found that an extinguished CS reconditioned more rapidly than a neutral stimulus. This apparent discrepancy may, perhaps, be reconciled by reconsideration of the pilot research conducted prior to the commencement of the present experiment. The results of the pilot

study indicated that 160 trials of extinction training was almost

sufficient to reduce conditioned fear to zero. Presumeably, then, there

is some optimal level between 160 and 320 trials of extinction that will

both reduce conditioned responding to its baseline rate and facilitate

reacquisition of the conditioned response. Since the present experiment

was concerned with effects of excessive amounts of extinction training

this optimal point was not determined. However in the light of the

findings obtained by Konorski and Szwejkowska (1950, 1952a) and Pavlov

(1927) in an appetitive situation, plus Kamano's (1968) results in a

conditioned fear situation, there is little doubt that such a level

exists in the present experimental setting.

In any event the question still remains as to the status of a

stimulus that has been extinguished beyond the point at which it will

reliably reduce a reflex to zero. The position to be taken here is

that the retardation of reacquisition observed in this study was due

to deficits in selective attention produced by excessive repeated

nonreinforcements. The well-documented finding that extinction to zero

is followed by enhanced reconditioning has already been explained quite

adequately in terms of an attentional mechanism. To briefly reiterate,

the notion is that simply extinguishing a conditioned response to zero

does not severely reduce the attention commanding properties of the

stimulus. That is, although response strength has been effectively

diminished, the strength of the analyzer associated with the detection

of the CS (Sutherland and Mackintosh, 1971) still remains above its

base level, thereby providing for accelerated reacquisition of conditioned

responding. However, it is not unreasonable to assume that further extinction training produces two additional sequential developments. Firstly, at some point the extinguished CS loses the remainder of its attention commanding properties (i.e. the analyzer strength reduces to its base level) and in this sense becomes "neutralized". That is, the CS is essentially returned to the status of a preconditioned stimulus. Secondly, it is proposed here, that continued extinction beyond the "neutralization" point leads to virtually the same decremental effects as those produced by simply nonreinforcing a neutral stimulus in isolation. According to this analysis, the phenomenon of extinction may be categorized into the following three distinct sequential stages depending upon the extent of nonreinforcement: (a) a reduction in response strength to zero, (b) a reduction in the remaining analyzer strength associated with detection of the CS, and (c) CS habituation. Thus the original "extinction beyond zero" phenomenon is reduced to nothing more than a post-conditioning CS habituation effect. Whether or not retardation of reacquisition occurs following extinction to zero is complete depends, of course, on how many additional CS alone presentations are administered.

Some indirect support for the above formulation accrues from the findings of Leaf et. al. (1968). These authors gave Ss 30 nonreinforced presentations of a stimulus either prior to or following Pavlovian fear conditioning. They discovered that the habituation and extinction procedures were equally effective in attenuating conditioned suppression. Since habituation and extinction produced quantitatively indistinguishable

effects, Leaf et. al. concluded that habituative nonreinforcement may be functionally as well as operationally similar to extinctive nonreinforcement.

In the present analysis we arrive at a similar conclusion except that the functional similarities between habituation and extinction do not occur until after the operation of extinction has rendered the previously excitatory CS "neutral". Therefore we do not agree with the Leaf et. al. (1968) conclusion that the available theories about extinction per se should be used as models for theories about habituation, since it is "extinction beyond zero" and habituation that are functionally similar.

It was suggested earlier that the results of this experiment would have an important bearing on Wagner and Rescorla's (1972) theory of Pavlovian conditioning as it applies to inhibition. The import attached to these results is even increased when taken into consideration in conjunction with those of Reiss and Wagner (1971). Both studies provide definitive evidence which affords the inference that simply repeatedly presenting a CS in the absence of cues associated with reinforcement is not a sufficient condition for the development of inhibitory tendencies. It will be recalled that the Wagner and Rescorla (1972) position advocates that the development of active inhibitory properties by a CS occurs only on those trials in which the CS is nonreinforced in compound with an aggregate of cues that signal the occurrence of reinforcement. This cue then, which is negatively correlated with reinforcement can only take on decrements and thus acquire a negative associative strength, which for

Wagner and Rescorla (1972) denotes the presence of inhibition. By ruling out experimental extinction as a sufficient condition for the development of conditioned inhibition, strong indirect support is provided for their model.

On the other hand, it is perhaps somewhat ironic that experimental extinction, one of the earliest phenomena that led Pavlov to postulate an inhibitory process, now seems to be better construed as an operation that is unrelated to the production of inhibition. This, of course, means that the development of conditioned inhibition may not be utilized as an explanation for the decrements in conditioned responding resulting from experimental extinction, leaving the process responsible for the phenomenon theoretically unresolved.

REFERENCES

Anderson, D.C., Wolf, D. & Sullivan, P. Pre-conditioning exposures to the CS: Variation in place of testing. <u>Psychonomic Science</u>, 1969, 14, 233-235.

Bull, J.A., & Overmier, J.B. Additive and subtractive properties of excitation and inhibition. <u>Journal of Comparative and Physiological Psychology</u>, 1968, 66, 511-514.

Carleton, P.L. and Vogel, J.R. Habituation and Conditioning. <u>Journal of Comparative and Physiological Psychology</u>, 1967, 63, 348-351.

Grove, P.M. and Thompson, R.F. Habituation: Dual Process Theory. <u>Psychological Review</u>, 1970, 77, 419-451.

Hammond, L.J. Retardation of fear acquisition when the CS has previously been inhibitory. <u>Journal of Comparative and Physiological Psychology</u>, 1968, 66, 756-759.

Hull, C.L. <u>Principles of Behavior</u>. New York: Appleton Century Crofts, 1943.

Kamano, D.K. Effects of an extinguished fear stimulus on avoidance behavior. <u>Psychonomic Science</u>, 1968, 13(5), 271-272.

Kimmel, H.D. Inhibition of the unconditioned response in classical conditioning. <u>Psychological Review</u>, 1966, 73, 232-240.

Konorski, J. <u>Conditioned Reflexes and Neuron Organization</u>. Cambridge: Cambridge University Press, 1948.

Konorski, J. <u>Integrative Activity of the Brain</u>. Chicago & London: The University of Chicago Press, 1967.

Konorski, J., & Szwejkowska, G. Chronic extinction and restoration of
conditioned reflexes. I. Extinction against the excitatory
background. Acta Biologiae Experimentalis, 1950, 15, 155-170.

Konorski, J., & Szwejkowska, G. Chronic extinction and restoration of
conditioned reflexes. III. Defensive motor reflexes. Acta
Biologiae Experimentalis, 1952, 16, 91-94. (a)

Konorski, J., & Szwejkowska, G. Chronic extinction and restoration of
conditioned stimulus (The principle of the primacy of first
training). Acta Biologiae Experimentalis, 1952, 16, 95-113. (b)

Leaf, R.C., Kayser, R.J., Andrews, J.S., Adkins, J.W., & Leaf, S.R.P.
Block of fear conditioning induced by habituation or extinction.
Psychonomic Science, 1968, 10, 189-190.

LoLordo, V.M., & Rescorla, R.A. Protection of the fear-eliciting
capacity of a stimulus from extinction. Acta Biologiae Experi-
mentalis, 1966, 26, 251-258.

Lubow, R.E. Latent inhibition: Effects of frequency of nonreinforced
pre-exposure of the CS. Journal of Comparative and Physiological
Psychology, 1965, 60, 454-457.

Lubow, R.E., & Moore, A.U. Latent inhibition: The effect of nonreinforced
pre-exposure to the conditional stimulus. Journal of Comparative
and Physiological Psychology, 1959, 62, 415-419.

Mosocovitch, A., & LoLordo, V.M. Role of safety in the Pavlovian
backward fear conditioning procedure. Journal of Comparative and
Physiological Psychology, 1968, 66, 673-678.

Pavlov, I.P. Conditioned Reflexes. London: Oxford University Press,
    1927.

Perelzweig, I.J. "Contributions to the Study of Conditioned Reflexes."
    Thesis, Petrograd, 1907.

Reiss, S., & Wagner, A.R. (1971). CS habituation produces a "latent
    inhibition effect" but no active conditioned inhibition. Learning
    and Motivation, in press.

Rescorla, R.A. Inhibition of delay in Pavlovian fear conditioning.
    Journal of Comparative and Physiological Psychology, 1967, 64,
    114-120. (a)

Rescorla, R.A. Pavlovian conditioning and its proper control procedures.
    Psychological Review, 1967, 74, 71-80. (b)

Rescorla, R.A. Pavlovian conditioned fear in Sidman avoidance learning.
    Journal of Comparative and Physiological Psychology, 1968, 65,
    55-60. (a)

Rescorla, R.A. Pavlovian conditioned inhibition. Psychological Bulletin,
    1969, 77-94.

Rescorla, R.A. & LoLordo, V.M. Inhibition of avoidance behavior. Journal
    of Comparative and Physiological Psychology, 1965, 59, 406-412.

Sidman, M. Avoidance conditioning with brief shock and no extroceptive
    warning signal. Science, 1953, 118, 157-158.

Siegel, S. Effect of CS habituation in eyelid conditioning. (1969).
    Journal of Comparative and Physiological Psychology, 68, 245-248.

Siegel, S. & Domjan, M. Backward conditioning as an inhibitory procedure.
    Learning and Motivation, 1971, 2, 1-11.

Spence, K.W. (1956). Behavior Theory and Conditioning. New Haven, Yale University Press.

Suboski, M.D., DiLollo, V., & Gormezano, I. Effects of unpaired pre-acquisition exposure of CS and UCS on classical conditioning of the nictitating membrane response of the albino rabbit. Psychological Reports, 1964, 15, 571-576.

Sutherland, N.S. and Mackintosh, N.S. Mechanisms of animal discrimination learning. (1971). New York: Academic Press.

Wagner, A.R., & Thomas, E., & Norton, T. Conditioning with electrical stimulation of motor cortex: Evidence of a possible source of motivation. Journal of Comparative and Physiological Psychology, 1967, 64, 191-199.

Wagner, A.R., & Rescorla, R.A. Inhibition in classical conditioning: Application of a theory. In R.A. Boakes and M.S. Halliday (eds.). Inhibition and Learning (1972). London: Academic Press, in press.

Weisman, R.G. & Litner, J.S. Positive conditioned reinforcement of Sidman avoidance behavior in rats. Journal of Comparative and Physiological Psychology, 1969a, 68(4), 597-603.

Weisman, R.G. & Litner, J.S. The course of Pavlovian excitation and inhibition of fear in rats. Journal of Comparative and Physiological Psychology, 1969b, 69(4), 667-672.

Weisman, R.G. & Litner, J.S. Role of the intertrial interval in Pavlovian differential conditioning of fear in rats. Journal of Comparative and Physiological Psychology, 1971, 74(2), 211-213.

FOOTNOTES

1. For a comprehensive presentation of the model see Wagner and Rescorla (1972).

APPENDIX A

ANALYSIS OF VARIANCE DATA RESULTS ON THE $\frac{CS}{PRE\ CS}$ RATIOS
OF CONDITIONED RESPONDING FOR ALL EXTINCTION GROUPS
FOLLOWING ACQUISITION, EXTINCTION, AND
REACQUISITION LEARNING.

TABLE A-1

Analysis of Acquisition Scores

Source	DF	MS	F
# Extinction Trials	3	.284	.258
Error	20	1.099	

TABLE A-2

Analysis of Extinction and Reacquisition Scores

Source	DF	MS	F
# Extinction Trials (A)	3	3.046	4.699**
Error	20	.648	
Test Phase (B)	1	.557	2.75
A x B	3	.198	.978
Error	20	.203	

** Significance at the .05 level of probability